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Abundance, Distribution and Dynamics of the American Oyster Population of the Public Fishing Area of Caraquet Bay, New Brunswick

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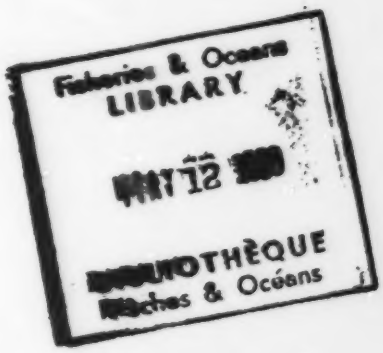

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ABSTRACT

A quantitative assessment of the distribution, abundance and population structure of the Public Oyster Fishing Area of Caraquet Bay, N.B. (latitude 47° 50'N) was conducted in June 1987. A standardization of the transect sampling protocol with previous studies permitted a comparison with data reported for 1974 and 1979. The distribution of the total oyster population (Crassostrea virginica) indicated that the general area of the bed has increased slightly (11%) from 1974 to 1987. The oysters exhibited a typical heterogeneous distribution over the bed which accounts for the large variability in the data. The total population of the main bed showed changes in the distribution of high (>100 ind m^{-2}), medium (10-100 m^{-2}) and low (<10 m^{-2}) density beds from 1974 to 1987. The high density river channel beds have retained their integrity and increased in area over time. The distribution of juvenile (length <35 mm), recruit (35-75 mm) and market size (>75 mm) oysters are also presented. In 1987, the average density as total number and market size oysters for the entire bed was 31.8 and 3.3 ind m^{-2} respectively. This was lower than that observed in 1979 (31.5 and 4.7 ind m^{-2}, respectively) and much lower than 1974 (63.5 and 11.3 ind m^{-2}, respectively). Analysis of the size frequency data collected in 1987 showed that the population structure for each of the identified beds was distinct and that recruitment varied among years.

RESUME

Une évaluation quantitative de la distribution, abondance et structure de la population du Banc Public de la Baie de Caraquet, N.-B., (latitude 47°50'N), a été fait en juin, 1987. Une standardisation de la méthode d'échantillionage sectionnée avec les autres études permettaient une comparaison avec les donnés pour les années 1974 et 1979. La distribution de la population totale d'huîtres (Crassostrea virginica) indiquait que la région du banc augmentait dans une faible mesure (11%) de 1974 à 1987. Le banc d'huîtres a eu un modèle de distribution hétéogène qui expliquait la grande variabilité des donnés. La population totale du banc principal indiquait des changements de la distribution haute (>100 ind m^{-2}), moyenne (10-100 m^{-2}) et basse (<10 m^{-2}) densité de 1974 à 1987. La haute densité des bancs du chenal ont retenu leur intégrité et augmenté en territoire avec le temps. La distribution d'huîtres de taille juvéniles, (taille <35 mm), recrue (35-75 mm) et la taille marchée (>75 mm) sont présentées. En 1987, la densité moyenne du nombre total et de la taille marchée pour le banc était 31.8 et 3.3 ind m^{-2}, respectivement. Elle était inférieure aux données observées en 1979 (31.5 et 4.7 ind m^{-2}, respectivement) et plus basse que 1974 (63.5 et 11.3 m^{-2}, respectivement). L'analyse des tailles de fréquence de 1987 indiquait que la structure de la population pour chacun des bancs identifiés étaient clairs et le recrutement était variable entre les années.

INTRODUCTION

The American oyster, Crassostrea virginica, is a common inhabitant of shallow bays and estuaries along the east coast of North America and the most northern commercially exploited population is located in Caraquet Bay, New Brunswick (latitude 47°50'N) (Medcof 1961, Lavoie 1977). Lavoie (1977) reviewed the redevelopment of the oyster fishery of Caraquet Bay after the original population was decimated by Malpeque disease in the late 1950's. Further, Lavoie (1977) and Lavoie and Robert (1981) have published the only quantitative population studies of the public fishing area of Caraquet Bay in an effort to provide the preliminary biological information required for management and development purposes.

Lavoie (1977) reported annual landing statistics for the Public Fishing Area from 1968 to 1976 and the average annual landing from 1971 to 1976 was 385t. Official landing statistics are not readily available for consecutive years since 1976 but information from the local Area Office in Tracadie (Ferguson pers. comm) indicate that recent landings for 1984 (300 t) and 1985 (361 t) are slightly lower than reported previously.

Lavoie (1978) examined the roles of the private and public sectors of the Caraquet Bay oyster fishery and found them to be dependent on this important and regionally dominant public fishing area. Both sectors remain concerned with the condition of the public fishing area particularly in view of recent development projects initiated to revitalize the industry. Recently, they again voiced grave concerns regarding the slow growth and high mortalities of bottom cultured oysters which, although addressed to a limited extent by Lavoie (1978) and Lavoie and Roberts (1981), remain unresolved. The high mortality of oysters on private leases in recent years have probably reduced overall annual landings but it is difficult to assess the magnitude of its impact because of the limited statistics available.

This report is an assessment of the distribution, abundance and structure of the oyster population of the public fishing area based on a quantitative study conducted in June, 1987. A standard sampling procedure, based on the previous studies of 1974 and 1979 by Lavoie (1977) and Lavoie and Robert (1981), will permit an examination of the changes that have occurred in the population since it was last surveyed in 1979. This present study was designed to obtain the baseline field data required to intitiate further studies on the biology and ecology of the Caraquet Bay oyster population.

MATERIAL AND METHODS

The Public Fishery Area of Caraquet Bay (Fig. 1) was sampled from 17-24 June 1987 using the transect method described by Lavoie (1977) and Lavoie and Robert (1981) and is briefly outlined here. Shore to shore transects were drawn on a hydrographic chart at approximately 200 m intervals and located in the field using sextant and land marks. Random samples were collected at approximately 150 m intervals along the transect and averaged 15 samples per transect. Sample position was recorded in the field using a sextant and three

arm protractor. A single $1m^2$ quadrat sample was collected at each station by divers handpicking all material within the quadrat. A 0.25 m^2 or 0.5 m^2 sample was collected in high density areas to avoid handling excessive quantities of material.

Samples were individually sorted from debris in the laboratory. All live oysters (>5 mm) were enumerated and maximum anterior - posterior length measured to the nearest 0.1 cm using calipers. A length/live weight regression was estimated from a sub-sample of 200 live oysters, to estimate live weight biomass. Individual live weight (whole animal in the shell) was determined by cleaning the shell of external debris and weighing to the nearest 0.01 g.

The data were used to map the distribution of the total population, the juvenile (length <35 mm) and market size (length >75 mm) oysters to delineate the low (<10 oysters m^{-2}), medium (10-100 oysters m^{-2}) and high (>100 oysters m^{-2}) density areas. The bed designations are the same as those used by Lavoie (1977) and Lavoie and Robert (1981) to facilitate describing the changes in total distribution between years. The hand drawn maps were digitized and a computer aided drafting package used to produce the final maps. The distribution maps of the 1974 (Lavoie 1977) and 1979 (Lavoie & Robert 1981) surveys were digitized and redrawn to scale for comparison with 1987.

A one-way ANOVA (SAS GLM) (SAS Institute 1985) was used to determine if there was a significant difference in the average density of total oysters and the different size categories among the beds for the 1987 data. A $\log_{10}(x+1)$ transformation was used to stabilize the variances and the Student Newman Keuls test used to locate significant differences. Quantitative data for the 1974 and 1979 surveys was not available for statistical comparisons among years.

The instantaneous rate of annual mortality (Z) (Ricker 1975) was estimated from the total size frequency distribution of the age classes of oysters from the 1987 data as described previously by Lavoie & Robert (1981) and is briefly summarized here. The von Bertalanffy growth curve of Lavoie & Robert (1981) (equation 1) was used to derive the age (year) classes from the length data and is:

$$Lt = 21.74\,(1 - e^{-0.071\,[0.243]}). \quad (1)$$

Z is estimated from the log tranformed equation (equation 3) in which Z is the regression coefficient:

$$Nt = No.\ e^{zt} \quad (2)$$

$$\log_e Nt = \log_e No + Zt \quad (3)$$

where: No is the number of oysters at t=0; and Nt is the number at age t (years).

RESULTS

SPATIAL DISTRIBUTION

The total distribution map for all size classes of oysters delineating the locations of the low, medium and high density areas (beds) is shown in Figure

2. The total area (excluding the Channel) was estimated to be 270 ha in 1987 (Table 1). The main medium density bed has a total area of 188 ha and is almost surrounded by a low density peripheral bed (60 ha). Three high density areas are found within the main bed, one towards the north shore, a similar sized one adjacent to the Rivière Caraquet channel and east of Pointe des Deux-Rivières and a smaller one south east of the Rivière Caraquet channel. They have a combined total area of 22 ha. The centrally located void within the main bed is a soft muddy silt area (divers' observations) and does not support oysters in measurable quantities. Both river channels have high concentrations of oysters in a well delineated but limited area (total area of 11 ha). Figure 3 shows that the distribution of market size (length >75 mm) oysters is relatively uniform throughout the public bed except for high concentrations in both channels. The majority of the channel oysters are unsuitable for market sale because of their twisted and nonuniform shape which results from the poor benthic growing conditions (Lavoie and Bryan 1981). Consequently, there is limited fishing pressure exerted on these channel beds.

The distribution of juveniles (length <35 mm) is shown in Figure 4 and the area of high concentration off the Pointe which corresponds well with the total distribution high density bed of Figure 2. This appears to be an area of high spatfall and/or survival. Once again, there are large concentrations of juveniles in the channel beds which were found growing on adult live oysters and empty shells. The juvenile oysters are found in higher concentrations towards the north, south and sides of the public fishing area with a medium density area located just north of the mud zone. Only a few are found along the east side of the public fishing area.

AVERAGE DENSITY

The average density of oysters (no. m^{-2}) for the total bed and each of the different beds identified in Figure 2 is shown in Table 2. Table 2 also shows the breakdown of the total density stock into legal size (length >75 mm), recruit (length 35-75 mm) and juvenile (length <35 mm) oyster components. The total overall bed has an average density stock of 48.6 m^{-2} while excluding the channel areas reduces the average to 31.8 m^{-2}. The average total standing stock of the low, medium, high density and channel areas is; 6.8, 30.9, 101.6, and 420.3 m^{-2} respectively. The density of all beds are significantly different from one another ($F=46.45$, d.f.=3,155, $p < 0.0001$) thus indicating that the spatial delineations of the bed are valid. Juveniles compose from 26% to 40% of the density for each bed with an overall average of 30% for the total bed (excluding the channel), whereas the recruits range from 38% to 62% with an overall average of 60%. The average density of the legal size oysters, recruits and juveniles for each area were significantly different from one another ($p < 0.0001$).

SIZE FREQUENCY DISTRIBUTION

The size frequency distributions of oysters collected from the low, medium and high density beds and the channel bed are shown in Figure 5 and for the total bed in Figure 6. The size distribution for the medium (main) density bed (Fig. 5) is unimodal with a peak at the 65-70 mm size interval but skewed towards the small size intervals. The proportion of juveniles is low when

compared with the other beds. The high density bed has a bimodal frequency distribution, with broad peaks at the size intervals 15 to 35 mm and 55 to 70 mm. There are very few oysters larger than 95 mm in this area as compared with other areas. Oysters of this size range are of at least the 1979 year class based on the growth curve of Lavoie and Robert (1981). The low density (peripheral) bed frequency distribution is similar to the high density bed. The channel bed is different from the others, with a peak in the distribution at the smaller sizes (25 to 30 mm) which declines gradually to the larger size classes (100 to 105 mm). There is a second peak in frequency (averaging 6.5%) in the largest size interval which reflects the pooling of the older oysters. In all cases, with the exception of the channel bed, there is a sharp decrease in the size frequency distributions after the legal size of 75 mm.

The total size frequency distribution (Fig. 6) is bimodal, with a broad peak from 15 to 35 mm (averaging 6%) and a second one from 60-75 mm (averaging 8%). The single spike in the largest size category reflects the pooling of the larger channel oysters. The lack of individuals in the small size classes of the frequency distribution indicates that there was very little natural recruitment to the overall population from the previous year's reproduction (i.e. 1986). The age class intervals as described by the growth curve of Lavoie & Robert (1981) are shown in Figure 6. It appears that natural recruitment to the Public Fishing Area appears to have been relatively stable from 1981 to 1986.

The rate of annual mortality (Z), estimated from the abundance of last 4 age classes of the total size frequency distribution, and was Z=0.94 (r^2=0.98, n=4). The 1987 Z is similar to that estimated by Lavoie and Robert (1981), that Z=0.88 for the 1979 oyster population.

The regression of total length (L) (mm) and live weight (whole in the shell) (W) (g) was estimated to be:

$$\log_{10}(W) = 2.83 \log_{10}(L) - 3.59 \quad (n=200,\ r^2=0.92,\ p<0.0001).$$

Lavoie and Robert (1981) reported that this regression was as follows in 1979; $\log_{10}(W) = 2.91 \log_{10}(L) - 3.75$ ($n=234$, $r^2=0.98$, $p<0.0001$). Comparison of the regressions indicate that oysters tended to be slightly heavier (for a given size) in 1987 than in 1979.

DISCUSSION

There have been changes in the overall size of the public fishing area (Table 1) from 1974 to 1987. The total area (excluding the channel beds) increased from 240 ha in 1974 to 290 ha in 1979 and has decreased slightly to 270 ha in 1987. Lavoie & Robert (1981) did not comment on the possible causes for the increase in area from 1974 to 1979 but the 20 ha decrease from 1979 to 1987 may be attributed to an overall decrease in the extent of the low density peripheral bed. These decreases appear to have occurred in the vicinity of the two river inflows and channels, and along the north and south shores where previously suitable oyster habitat has apparently deteriorated. Diver observations indicate that the substrate condition is quite soft and flocculent. Although the overall size of the Public bed has decreased since 1979, it remains larger than that estimated in the 1974 survey.

The distribution maps of oyster densities for 1974 and 1979 were redrawn to a common scale and are shown in Figure 7 and Figure 8, respectively. The high density beds first noted in 1974, were not evident in the 1979 survey but were well defined in the 1987 data analysis. This change in density has been documented in the size frequency histogram for the high density beds of 1987 (Figure 5) which indicates that there are few animals of the 1979 year class and older; the approximate time when no high density beds were identified. The size and positions of these high density beds have changed from 1974 to 1987, decreasing in total area by 55% and becoming less contiguous. The total area and extent of the medium density (main) bed has remained relatively constant from 1979 to 1987. That the central area void of oysters was observed in 1974 and 1987, but not in 1979, may be the result of changing substrate conditions and the patchy distribution exhibited by oysters, and the resulting sampling errors. The channel bed of Rivière Caraquet has increased in size from 1979 to 1987 and the small channel bed of Rivière Nord has become larger. This expansion may be due to a lack of fishing pressure being exerted on these areas because of the general poor oyster quality. The bottom conditions of channels are typically poor commercial oyster habitat and the shells became deformed in the soft bottoms (Galtsoff 1964, Lavoie 1977). Oysters occur commonly in clumps (Galtsoff 1964) and areas of high density, with a large percentage of young oysters, may indicate a region of natural recruitment (i.e. spatfall accumulation and survival) (Haven et al. 1987). Therefore, the channel beds and the high density bed adjacent to the Pointe may be areas of natural larval retention and high spatfall and this may be investigated in the near future.

The total average density of oysters decreased 50% from 1974 to 1979 (63.5 m^{-2} to 31.5 m^{-2}) and remains at that level in 1987 as shown in Table 3. The density of market size oysters decreased from 11.3 m^{-2} in 1974 to 4.7 m^{-2} in 1979, and decreased further to 3.3 m^{-2} in 1987. Expressed in other terms, the available biomass of legal (market) sized oysters in boxes and metric tons has fluctuated similarly as also shown in Table 3. The reduced density of market size oysters on the main and high density beds will appear as a reduction in total landings for the area even though oyster quality may improve over time (Lavoie & Bryan 1981). The average density and biomass estimates of market size oysters in 1987 may be lower than expected when compared with the early surveys due to the time of year when the sampling was conducted. The 1974 and 1979 surveys occurred from mid to late August while the 1987 assessment was done in June. Presumeably, an early survey would show a lower (albeit small) percentage of market oysters than one conducted in August due simply to shell growth over the summer.

The total density of the low density peripheral bed almost doubled from 1974 to 1987 (Table 3) while that of the high density bed halved. The density of the main medium density bed has fluctuated and is now at levels lower than recorded previously. The channel bed standing stock, although the bed was not identified in 1974, has increased almost 4 fold from 1979 to 1987 probably as a result of insignificant fishing pressure. This may also explain the peculiarity of the channel bed size frequency distribution compared with the other beds.

The high density oyster beds were not observed in 1979 and Lavoie and Robert (1981) suggested that the reduced density would be beneficial in increasing the overall market quality of oysters growing in the public fishing area. High densities of oysters reduces the shell quality due to the physical contact of overcrowding. However, reducing the density tends to provide better shell quality for increased dollar value for market sales in the half shell and Statistics are not available to show if the increased oyster quality resulted in increased landed value in dollars. The estimated total boxes of market size oysters for the entire public fishing area was 56,628 and 31,410 boxes for 1974 and 1979 respectively, and was estimated to be 19,800 boxes in 1987. Unfortunately, landing statistics are not available for comparison purposes with those reported earlier by Lavoie (1977).

Comparison of the total size frequency distribution of 1974, 1979 and 1987 (Figure 6) indicates that the high levels of juvenile recruitment observed in 1974 have not been witnessed since those times. Juvenile recruitment may be periodic but it is not evident from the distributions if it is cyclic in Caraquet Bay. However, the dearth of juveniles in the 1986 year class is supported by comments from local aquaculturalists who indicated that 1986 was extremely poor for spat collection while 1987 was a dismal failure. In any event, the public fishery has been sustained by these recruitment periods as evidenced by the year class analysis, and the present fishery is based on the 1981 and 1982 year classes. Peaks and troughs in the size frequency distribution and sporadic recruitment are very characteristic of most bivalve mollusc populations (Loosanoff 1966, Powell & Cummins 1985).

It appears that the oyster population of the Public Fishing Area has stabilized at a population level lower than that recorded in 1974 and 1979. Recruitment remains sporadic but sufficient to maintain the population. Although no growth rate estimates were attempted with the 1987 data collected, the phenonmena of increased mortalities of oysters found on private leases in Caraquet Bay necessitates a detailed investigation of fishing and stocking practices of private lease holders, as well as specific studies of rates of natural mortality under lease conditions.

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TABLE 1 Comparison of the physical area (hectares) of total bed and the different density beds of the Public Fishing Area of Caraquet Bay for 1974, 1979 and 1987.

BED	1974[1] (ha)	1979[2] (ha)	1987 (ha)
LOW	61	86	60
MEDIUM	139	204	188
HIGH	40	N/A	22
CHANNEL	N/A	3	11
TOTAL (without channel)	240	290	270

[1] Lavoie 1977
[2] Lavoie & Robert 1981

TABLE 2 Average density (no. m^{-2}) of oysters for each of the size categories and density beds of the Public Fishing Area of Caraquet Bay in 1987.

BED	NUMBER OF SAMPLES	TOTAL NUMBER (n±SE)	LEGAL SIZE (>75mm) (N±SE)	RECRUIT (35-75mm) (N±SE)	JUVENILE (<35mm) (N±SE)
LOW DENSITY	35	6.8 ± 2.78	0.7 ± 0.24	3.4 ± 1.19	2.7 ± 1.43
MEDIUM DENSITY	106	30.9 ± 2.06	3.7 ± 0.35	19.2 ± 1.45	7.9 ± 0.86
HIGH DENSITY	14	101.6 ± 15.69	6.8 ± 1.46	57.7 ± 9.56	37.1 ± 8.87
CHANNEL	7	420.3 ± 70.35	119.6 ± 37.01	158.7 ± 32.73	142.0 ± 31.31
TOTAL BED	162	48.6 ± 7.35	8.4 ± 2.40	25.1 ± 3.08	15.1 ± 2.74
TOTAL (without channel)	155	31.8 ± 2.83	3.3 ± 0.31	19.1 ± 1.73	9.4 ± 1.25

TABLE 3 Comparison of total average density (no.m-2) and legal size (length >75mm) density for (no.m-2) for each of the different density beds and the total bed of the Public Fishing Area of Caraquet Bay for 1974, 1979 and 1987. An estimate of the available legal size biomass (excluding channel estimates) in the form of metric tons* and boxes* is also shown for comparison purposes.

BED	1974[1]		1979[2]		1987	
	TOTAL (No.m-2)	LEGAL (No.m-2)	TOTAL (No.m-2)	LEGAL (No.m-2)	TOTAL (No.m-2)	LEGAL (No.m-2)
LOW	3.6	0.8	2.7	0.4	6.8	0.7
MEDIUM	36.2	5.9	43.7	6.7	30.9	3.7
HIGH	250.5	46.1	N/A	N/A	101.6	6.8
CHANNEL	N/A	N/A	142.5	28.3	420.3	119.6
TOTAL BED (excluding channel)	63.5	11.3	31.5	4.7	31.8	3.3
TOTAL BOXES* LEGAL SIZE OYSTERS		56,628 boxes		31,410 boxes		19,800 boxes
TOTAL METRIC TONS (t) OF LEGAL SIZE OYSTERS		2,574t		1,282t		808t

1 Lavoie 1977
2 Lavoie and Robert 1981
* One metric ton contains 24.5 standard oyster boxes which contain 450 - 500 legal size oysters per box. (Lavoie 1977)

Figure 1. Location of the Public Oyster Fishing Area in Caraquet Bay (latitude 47° 50'N), New Brunswick, Canada.

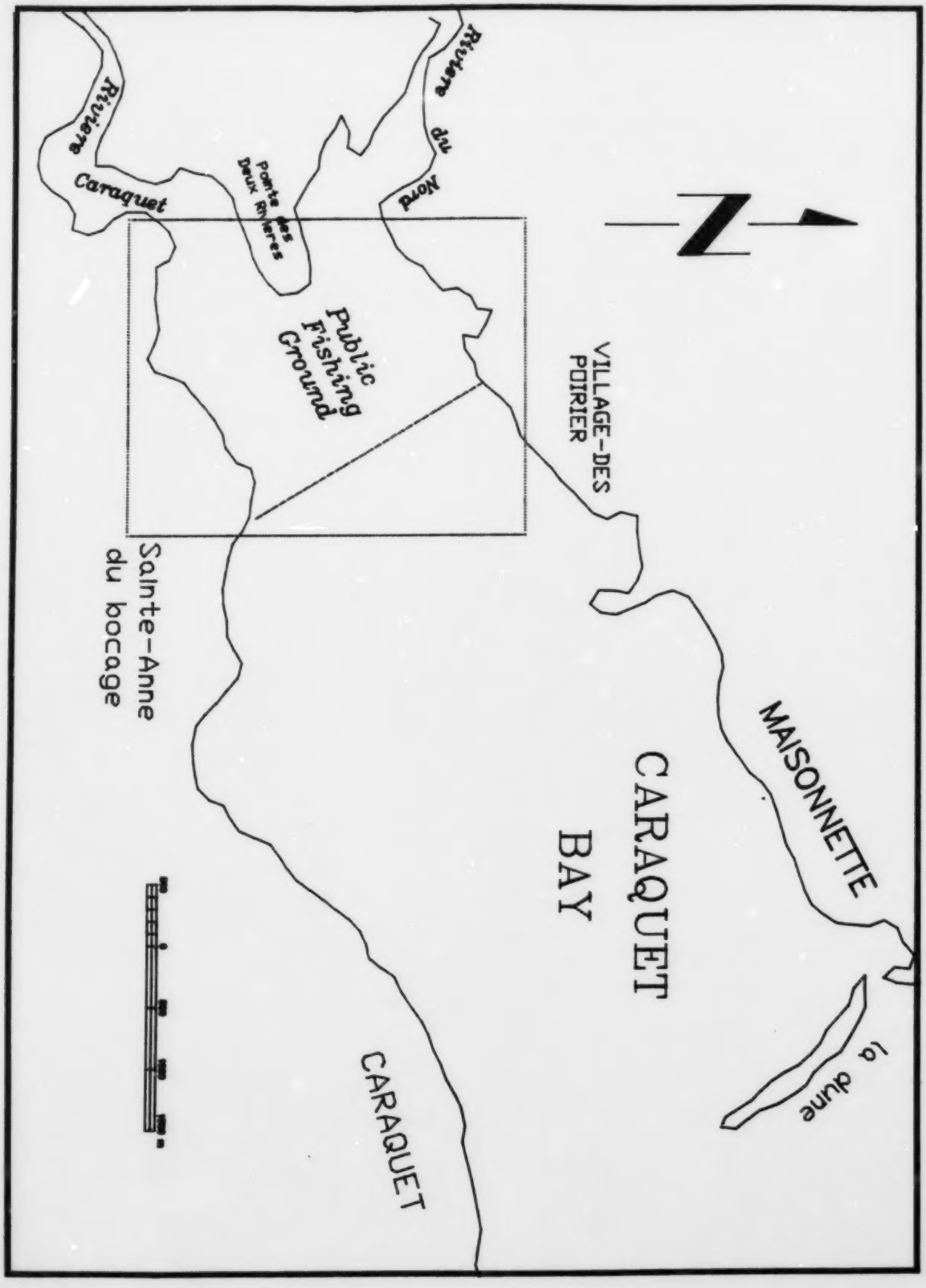

Figure 2. Distribution of the total oyster (Crassostrea virginica) population showing the different density beds and channel beds of the Public Fishing Area of Caraquet Bay in 1987.

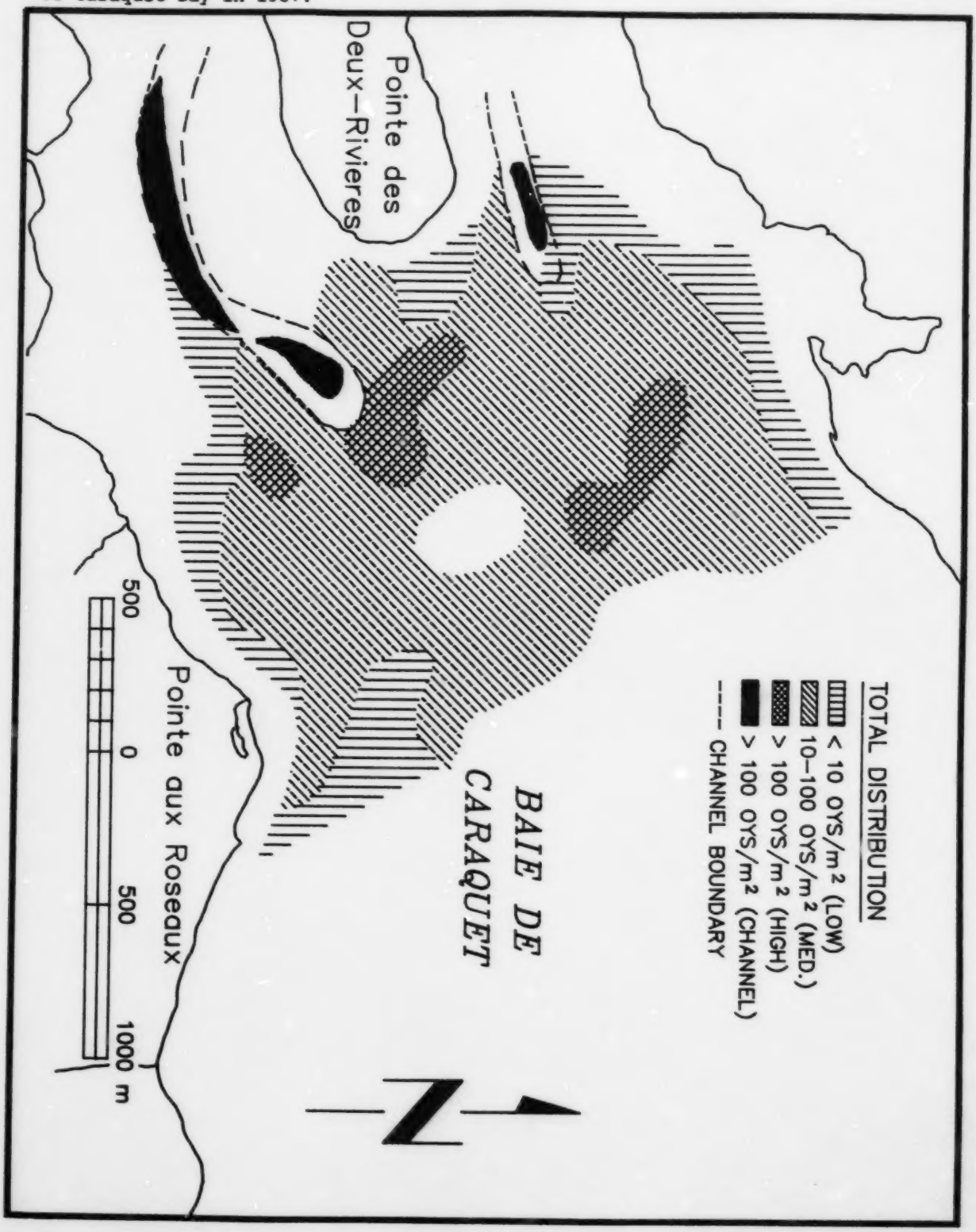

Figure 3. Distribution of the market size (length > 75mm) oysters (Crassostrea virginica) of the Public Fishing Area of Caraquet Bay in 1987.

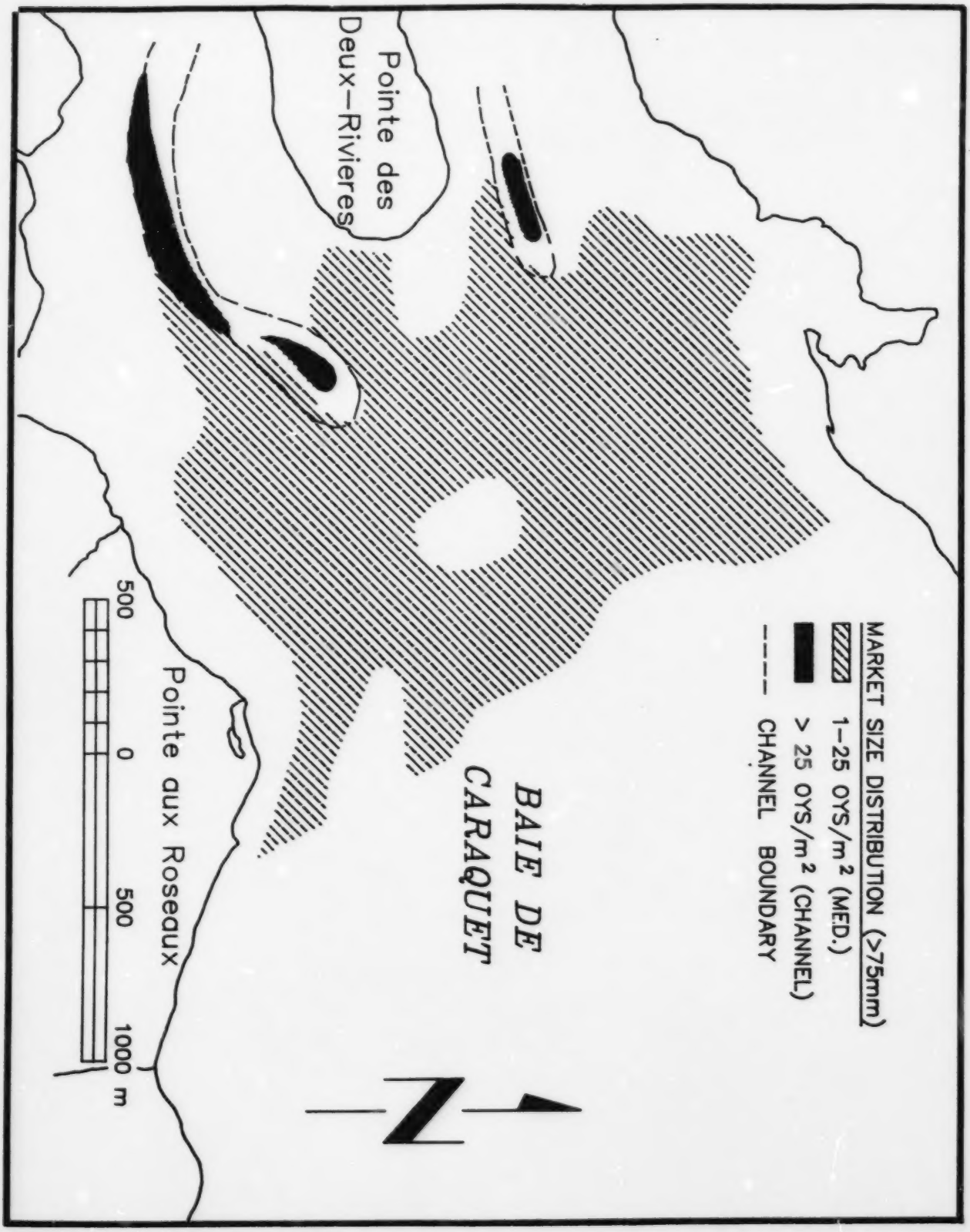

Figure 4. Distribution of the juvenile size (length < 35mm) oysters (Crassostrea virginca) of the Public Fishing Area of Caraquet Bay in 1987.

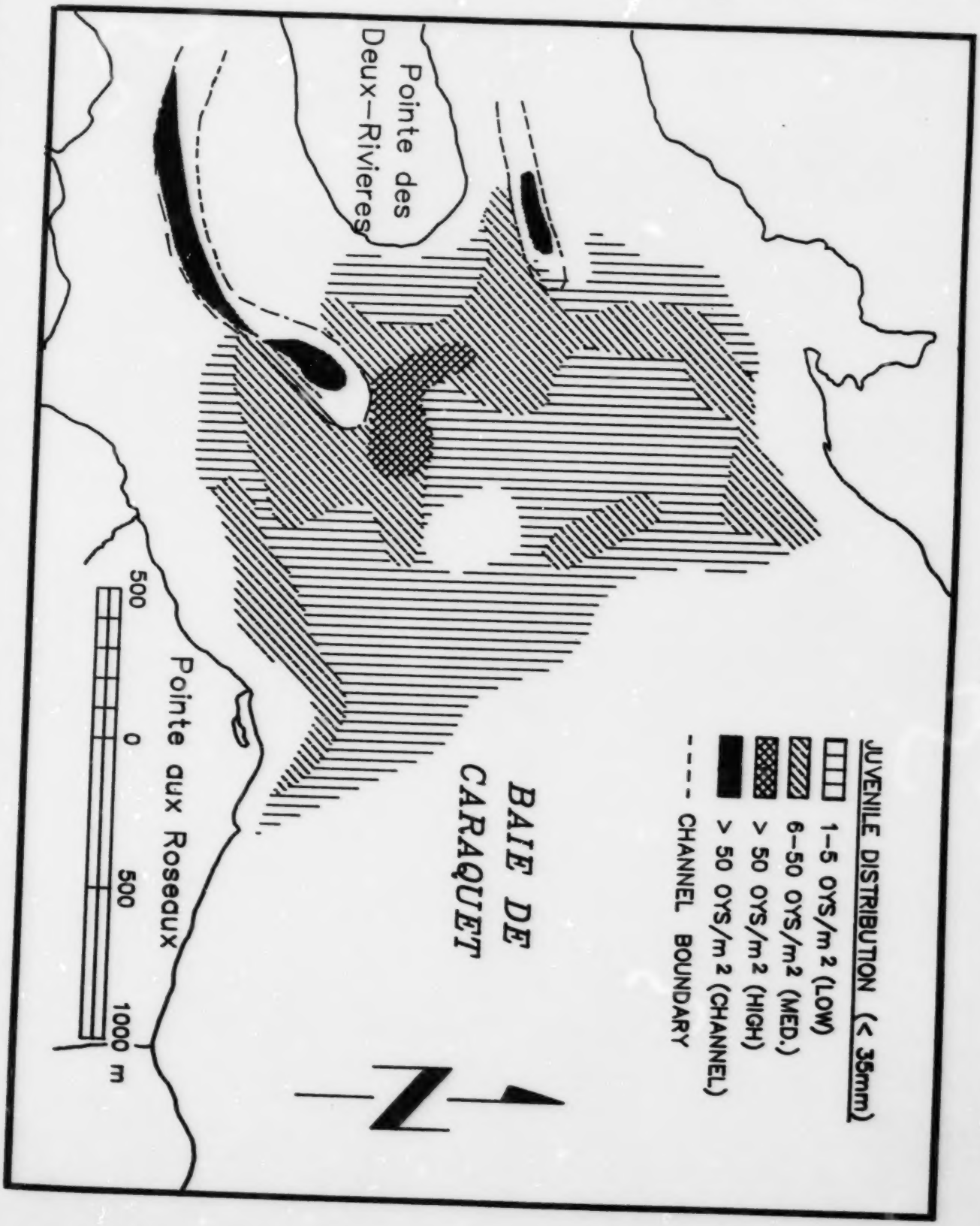

Figure 5. Size frequency distribution of oysters (Crassostrea virginca) of the low, medium, and high density beds and the channel bed of the Public Fishing Area of Caraquet Bay in 1987.

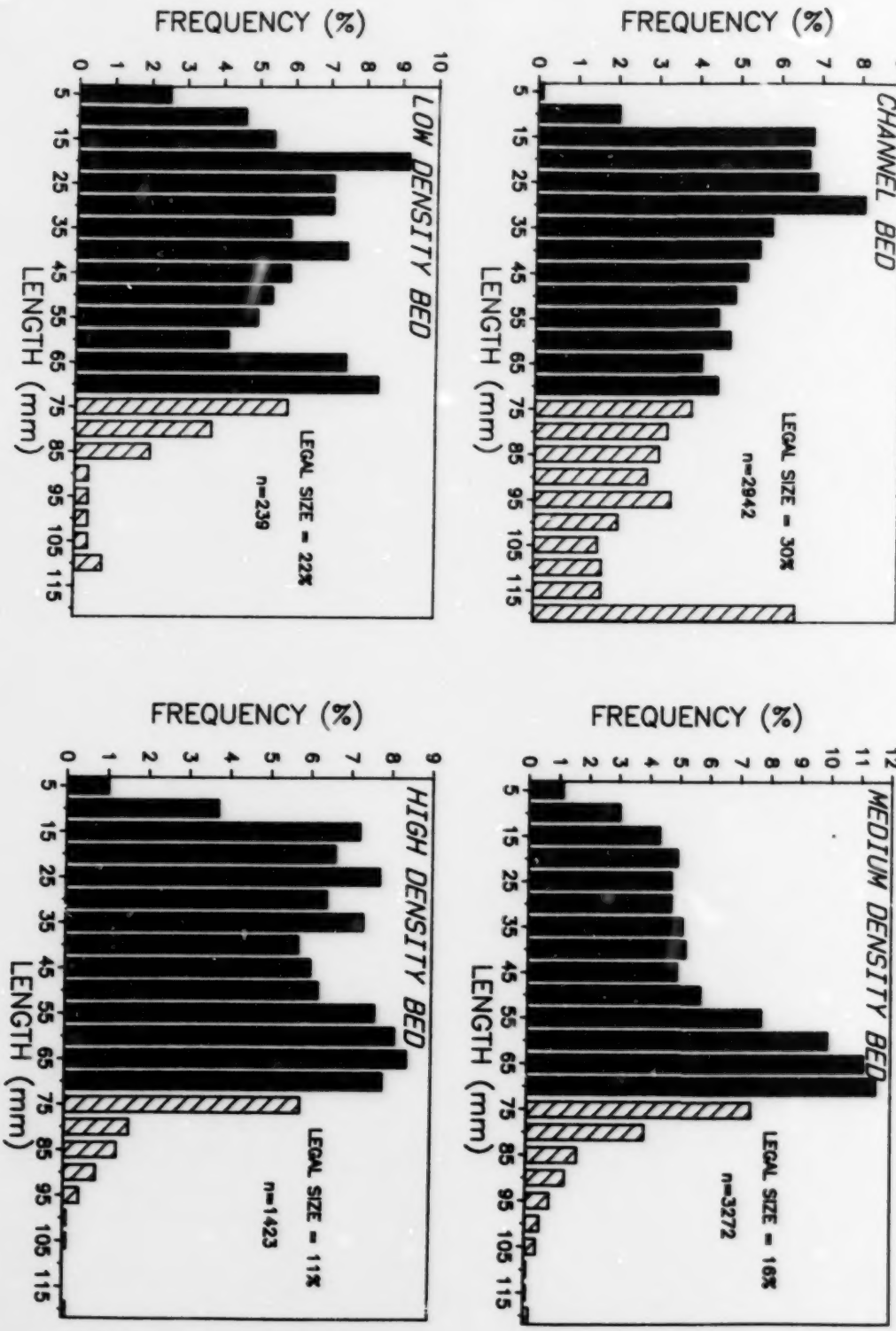

Figure 6. Size frequency distributions of the total oyster (Crassostrea virginica) population of the Public Fishing Area of Caraquet Bay in 1987, 1979, and 1974.

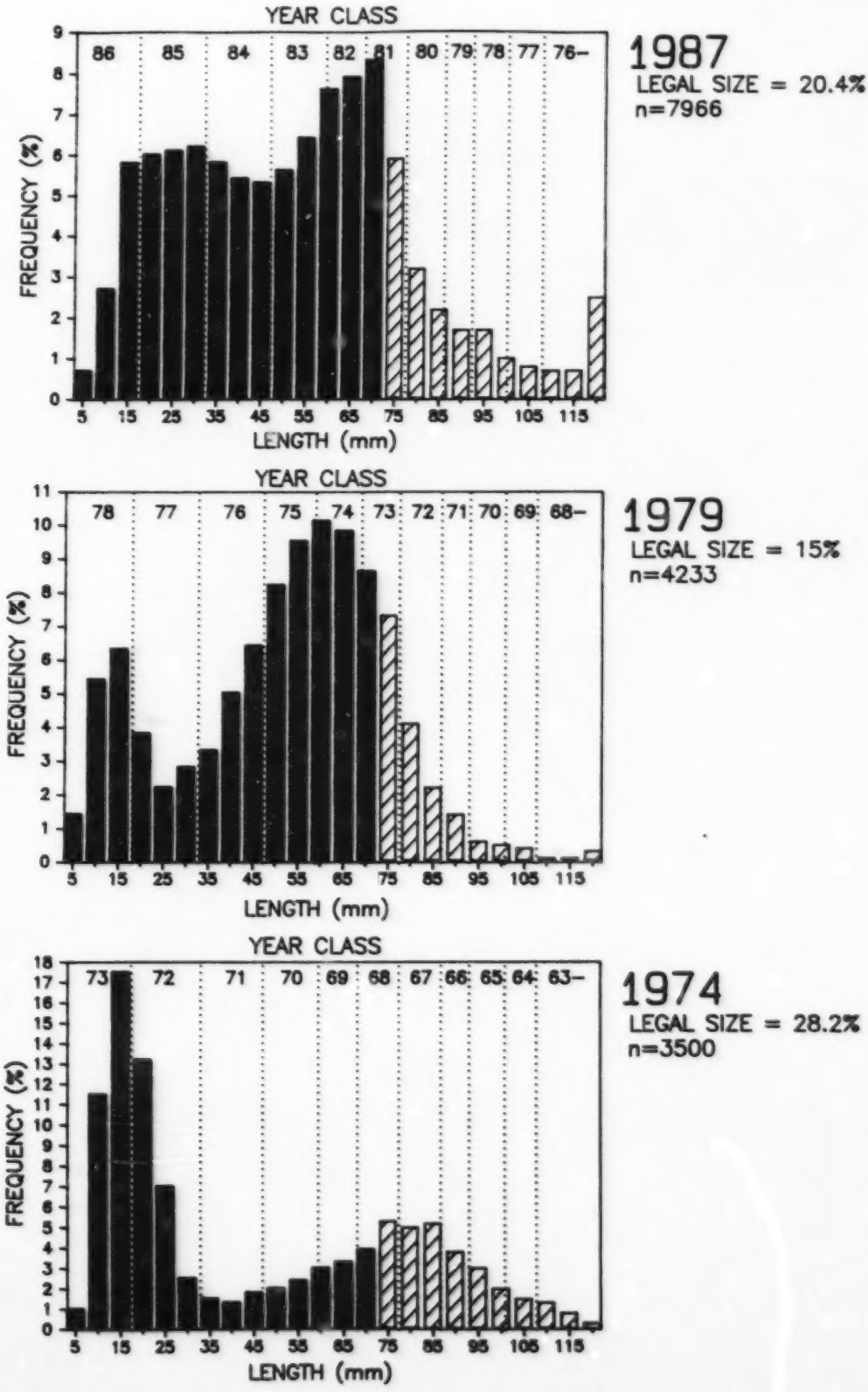

Figure 7. The distribution of the total oyster (Crassostrea virginica) population of the Public Fishing Area of Caraquet Bay in 1974.

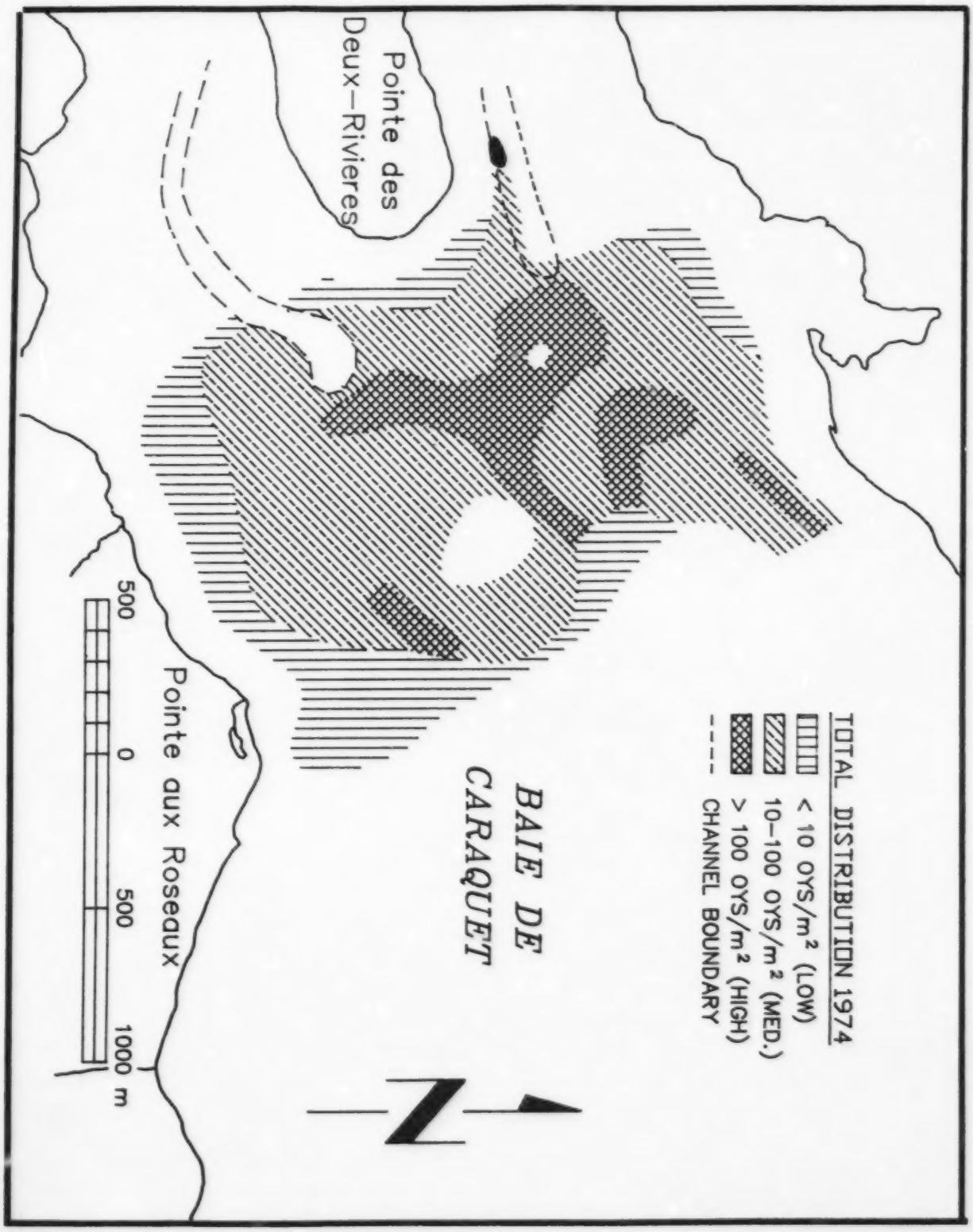

Figure 8. The distribution of the total oyster (Crassostrea virginica) population of the Public Fishing Area of Caraquet Bay in 1979.